UNIVERSITY OF MINNESOTA

SPACE SCIENCE CENTER

A STUDY OF MINNESOTA FORESTS
AND LAKES USING DATA FROM ERTS

December 31, 1972

NASA GRANT NGL 24-005-263

ON THE COVER — The area of the heavens around the Orion Constellation, shown in the cover photograph made through the 120-inch telescope of the Lick observatory, is also the region of observations with an infrared telescope developed by University of Minnesota astro-physicists. The infrared sensory equipment reveals stellar bodies that could not be studied by conventional telescopes, and it is expected to provide data on the birth of stars.

SPACE SCIENCE CENTER

University of Minnesota

Minneapolis, Minnesota 55455

"A STUDY OF MINNESOTA FORESTS AND LAKES USING DATA FROM EARTH RESOURCES TECHNOLOGY SATELLITES."

SIX-MONTH PROGRESS REPORT

December 31, 1972

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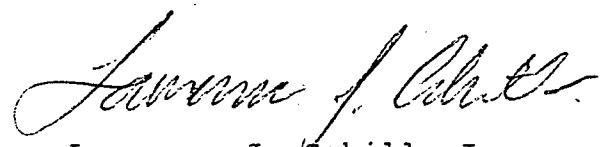
SPACE SCIENCE CENTER

PROGRESS REPORT

7/72 Through 12/72

FOREWORD

This report covers the first six-month period, 1 July 1972 to 31 December 1972 of support under NASA Grant NGL 24-005-263. The purpose of this project is to foster and develop new applications of remote sensing under an interdisciplinary effort with the general title "A Study of Minnesota Forests and Lakes Using Data from Earth Resources Technology Satellites." The following seven reports make up the specific projects presently being conducted by eight investigators throughout the State of Minnesota in co-operation with several agencies and municipalities.



Laurence J. Cahill, Jr.
Director, Space Science Center

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Introduction

At the time of establishment of this project, the Institute of Agriculture Remote Sensing Laboratory initiated the following investigations:

"Forest Vegetation Classification and Inventory."

Investigator: Dr. M. Meyer, Director, Institute of Agriculture, Remote Sensing Laboratory, College of Forestry.

"Soil Classification and Characterization."

Investigator: Dr. R. Rust, Professor, Department of Soil Science, College of Agriculture.

"Hydrologic Evaluation of Peatlands."

Investigator: Dr. A. Mace, Head, Department of Forest Biology, College of Forestry.

"Remote Sensing of Plant Disease."

Investigator: Dr. D. French, Professor, Department of Plant Pathology, College of Agriculture.

In view of its 20-plus years of involvement in both instruction and research in applications of remote sensing to resource management, the Institute of Agriculture Remote Sensing Laboratory was adequately prepared in terms of trained personnel, laboratory facilities and equipment (aerial cameras, photo aircraft and image analysis equipment) to move quickly into the field, establish test sites, execute overflights and commence gathering ground truth.

Although the four investigators listed above are the primary investigators for the overall subproject, additional scientists in the institute of Agriculture have since become involved[1] and their activities are also accounted for in the report which follows. Because of the close proximity and relationships of the various disciplines, research projects and research scientists in the Institute, it was possible (at little additional cost) to realize a number of good "targets of opportunity" during the 1972 field season and to add substantially to the total number of subprojects involved to date. In at least two cases (corn defoliation and alfalfa pest identification and management), research on remote sensing applications had already been under way for about 2 years and this project provided the means to carry them beyond the feasibility exploration stage to one of preparation in practical application trials.

Wherever possible, investigators and students were involved in the projects to provide a maximum number of persons and disciplines with working experience in remote sensing applications. A brief description of project organization, work accomplishments, and work planned for the period January - June, 1973 follows.

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[1] Dr. H. Chiang, Prof. of Entomology, Dept. of Ent., Fish. & Wild., Coll. of Agr.; Dr. D. Barnes, Res. Geneticist (USDA, ARS), Dept. of Agron. and Plant Gen., Coll. of Agr.; Prof. R. Douglass, School of For., The Penna. State Univ., Mont Alto; Dr. R. Wilcoxson, Prof., Dept. of Plant Path., Coll. of Agr.; Dr. E. Radcliffe, Assoc. Prof., Dept. of Ent., Fish. & Wild., Coll. of Agr.; Dr. F. Froscheiser, Res. Plant Pathologist (USDA, ARS), Dept. of Plant Path., Coll. of Agr.; Dr. R. Stucker, Assoc. Prof., Dept. of Agron. and Plant Gen., Coll. of Agr.

Investigation Status

I. HYDROLOGIC EVALUATION OF PEATLANDS (A. Mace)

Work Completed: A low altitude photographic flight was made over Grave, Spring and Burrows Lakes in Itasca County on September 8, 1972, for the purpose of determining the feasibility of utilizing multi-spectral images to identify and quantify aquatic types of vegetation. The following four film/filter combinations were used:

Film/Filter	Bandwidth (u)
Plus-X/25A	0.6-0.7
Plus-X/58	0.5-0.6
IR B&W/89B	0.7-0.9
Ekta IR/15,20C	0.5-0.9

At least one pass was made over each lake to provide scales of 1:12,000 and 1:36,000.

Concurrent with the overflight, data were collected from each lake to identify, quantify, and locate types of aquatic vegetation for correlation with multispectral images. Broadleaf vegetation and reeds were mapped according to species and density utilizing counts per unit area and a grid system. Algal populations were determined by collection of a liter sample at grid points and fixing the algae with lugol's solution. Microscopic examination of each sample permitted identification and number of organisms per liter. Also, identification and density determination of submerged vegetation were made in shallow areas.

One lake is being used to train an analyst for identification of various species in other lakes using image enhancement techniques. Preliminary results indicate that species identification with aerial photography is possible.

Work Planned: The film chips currently under preparation will be analyzed both by means of the Laboratory's I^2S 6030 image combiner and ISI VP-8 density slicer to correlate density of large aquatic vegetation and concentration of algal population with ground truth data. Following data analyses, a final report will be prepared and submitted and the findings submitted for possible publication in a suitable journal.

II. FOREST VEGETATION CLASSIFICATION AND INVENTORY (M. Meyer and R. Douglass)

Work Completed: Vegetation classification maps of the northern portion of the Chippewa National Forest in Northern Minnesota were prepared (both on the basis of existing District maps and additional field work and photo interpretation). This being the location of NASA Test Site No. 197 (Univ. of Minn. College of Forestry), NASA aircraft overflights had been accomplished on it since 1968. Using the RB57F overflight imagery from the August and September, 1971, an experiment to determine the applicability of this photography to large-area forest management was established. A number of the technical personnel of the National Forest volunteered to do the interpretation and, following a period of specialized training, were asked to identify (and classify) various forest and nonforest vegetation types on the color and color infrared 1:60,000 and 1:120,000 scale 9x9-inch format photography and on the various 1:462,000 scale B&W film/filter combinations achieved with the RB57F 70mm camera package.

They were amazingly successful in their efforts - far beyond what they (or we) anticipated was possible with such small scale photography. The project has been prepared for a publication titled "Remote Sensing Applications to Forest Vegetation Classification and Conifer Vigor Loss Due to Dwarf Mistletoe" which is being edited by the USDA-Forest Service, Pacific Southwest Forest and Range Experiment Station for publication under the terms of a

research contract with the Earth Resources Survey Program, Office of Space Sciences and Applications, NASA.

Work Planned: Since we now have excellent ERTS coverage of the same area, a broad vegetation map of the entire forest will be prepared from ground and low altitude aerial photography data. This "ground truth" map will then be compared with ERTS imagery and the extent of capabilities of ERTS imagery for such mapping purposes will be ascertained. Upon completion, a final report will be filed and publication of the results considered.

III. REMOTE SENSING OF PLANT DISEASE (D. French and R. Douglass)

Work Completed: Remote sensing applications to black spruce stands for detecting the dwarf mistletoe disease were studied by means of low-, medium- and high-altitude multispectral aerial photography employing film/filter combinations suggested by an earlier tower-tramway study.

Color infrared, at a range of scales, proved to be the most effective film, not only because of the contrast between healthy and diseased vegetation, but also because of the clearer pictures at extremely high altitudes. Dwarf mistletoe infection centers of 0.1 acre were visible on color infrared film at scales as small as 1:118,000, however, centers this small were difficult to detect at scales from 1:63,360 to 1:118,000 without magnification and high contrast rendition. Openings only 0.25 acre in size were visible at a scale of 1:462,000. With low altitude photography (scale of 1:2,640) using Ektachrome MS film, it has been possible to detect infection centers no more than 10 feet in diameter, and to separate between trees killed by dwarf mistletoe and trees dead from other causes. The following table summarizes accomplishments to date:

Photo scale	Infection center detectability
1:8,000	0.1 acre centers easily detected
1:31,680	0.1 acre centers detectable
1:59,000	0.1 acre centers detectable
1:63,360	Individual 0.1 acre centers difficult to detect
1:118,000	0.1 acre centers detectable on color IR, but with difficulty. Magnification needed on color photography to detect 0.1 acre openings
1:462,000	0.1 acre centers not detectable, 0.25 acre centers visible

Work Planned: Although we have accumulated considerable data involving the detection of dwarf mistletoe, we need to further perfect the techniques. Image enhancement, by means of optically combining multispectral imagery and the masking and density - slicing of single emulsions tended to improve the ease of detection but did not improve, or extend, the actual threshold of detection. Further study, however, may lead to detection at higher altitudes. Everyone concerned with forest management is in need of a more effective means of detecting tree diseases.

Other diseases which need to be detected by remote sensing are hypoxylon canker of aspen, oak wilt, Dutch elm disease, and root rots of pines. Many agencies are interested in the development of detection systems which are crucial to management and control programs. Our initial studies with these diseases have been promising but much more development (which is planned for this period) is required before remote sensing can be used on an operational basis.

IV. SOIL CLASSIFICATION AND CHARACTERIZATION (R. Rust)

Work Completed: Principal effort during this period has been directed to (1) establishing ground truth data in physiographic area of Agassiz Lake Plain where soils with salinity problems occur; taking soil samples for conductivity analyses in same crop or follow area where saline and non-saline conditions occur; (2) obtaining underflight imagery in various film/filter combinations to approximate same spectral bands as available in ERTS-A MSS imagery (Plus X/25A; Plus -X/58; IR B&W/89B, and Aerochrome IR 2443/20C, 15 at scales of 1:20,000 and 1:64,570); (3) obtaining Kodachrome and Ektachrome photography at approximately 1000 feet during time of maximum expression of vegetative response to salinity (Aug. 12, 1972); (4) making detailed soil surveys (scale 1:20,000) along selected 10-mile transects in Kittson County in the soil areas having salinity problems.

Prelimiary observations and conclusions:

1. Acceptable ERTS-A MSS imagery has been minimal, apparently due to higher than average cloud cover condition.
2. Bulk imagery viewed appears to be most useful in band 5.
3. Precision processed imagery received has been minimal in terms of request. That received does not appear to be satisfactory for image analysis (density slicing) due to 'tonal banding' apparently related to processing.
4. Underflight imagery (scale 1:20,000) is mostly of bare ground condition (October 24, 1972) and does not appear to

be as useful as imagery taken in early August in visual companions of saline soil areas.

5. Image analysis and color additive equipment not available during most of this period. Final conclusions to be drawn on basis of use of this equipment.

Work Planned: Work to be accomplished during the next 6-month period consists of (1) image analysis with density slicing techniques, (2) image enhancement and analysis by multispectral combining and (3) visual interpretation to relate salinity conditions on test fields to imagery and, later, to other areas in Kittson County along ground/photo transects. Upon conclusion, a final report will be prepared.

V. REMOTE SENSING APPLICATIONS TO ALFALFA MANAGEMENT AND PEST IDENTIFICATION (D. Barnes, F. Frosheiser, M. Meyer, E. Radcliffe, R. Stucker and R. Wilcoxson)

Work Completed: A nine acre alfalfa study, with 1/3 acre plots was established in 1971 at the Minnesota Agricultural Experiment Station at Rosemount, Minnesota. The study was designed so that the effects of diseases, insects and stage of plant growth could be monitored weekly in order to follow changes in the ecosystem of 5 alfalfa varieties. A total of 8 multispectral overflights at scales of 1:15,840, 1:6,336 and 1:4,800 were accomplished at intervals during the 1972 growing season. The following 70mm/film/filter combinations were used (selected on the basis of preliminary feasibility tests flown in 1971):

Panchromatic Plus-X/Wr 58

Panchromatic Plus-X/Wr 25A

Aero Infrared/Wr 89B

Ektachrome IR/Wr 15

The films are now being catalogued and prepared for analysis by means of the Laboratory's I^2B 6030 Image Combiner and X ISI VP-8 density slicer.

Work Planned: Complete the film preparation and compare the ground truth data at each overflight date with photo-image data. The photo-image data will include (1) visual photo interpretation, (2) multispectral image enhancement, with various band/filter combinations, and (3) results from using density slicing techniques on the more promising spectare bands.

A final report on the relationships between various types of photo-imagery and ground truth data will be prepared for publication. It is planned that these studies will indicate the potential of remote sensing as a means of surveying the growth stage and production problems of alfalfa.

VI. REMOTE SENSING OF SIMULATED DEFOLIATION BY INSECTS IN CORN

(H. Chiang and M. Meyer)

Work Completed: Multispectral, multiscale and multidate 70mm aerial photography had been accomplished during 1970 and 1971 of simulated corn defoliation by grasshoppers and army worms. The results provided several guidelines for using aerial photography for detecting defoliation: (1) Defoliation in corn may be detected with equal reliability regardless of row direction. (2) Detection is feasible with photographs taken as immediately after defoliation as 1 day; it is not necessary to wait for intensive plant stress. (3) Detection is equally feasible when plants are at the 11-leaf stage through tasselling. (4) The scale of 1:6,336 gave most reliable detection, but considering the economics, the scale of 1:15,840 is to be recommended. (5) Aero infrared film with Wratten 89B filter gave the best results among the 7 combinations tested. (6) Morning flights are to be recommended. (7) Defoliation on top of plant is easier to detect than that on the basal part of the plant.

Although the detectability of various levels of defoliation had been established by conventional photo interpretation methods (i.e., filtering, light tables, magnifying stereoscopes), no in-depth study of the effects of various types of image enhancement (combining, density-slicing) upon detectability thresholds had been accomplished (not previously possible). Both the added laboratory analysis facilities and the funds for image preparation provided by this NASA project have made it possible to extend the capabilities of the study.

Work Planned: The manuscript for the original work (which had been prepared, and tentatively accepted for publication by the Journal of Economics) is being revised to incorporate the results of this further treatment of the photo imagery. During the next work period, the photo enhancement and its analysis will be completed, and the manuscript updated to include the findings. The various types of multispectral imagery to be analyzed include the following:

Panchromatic Plus-X/Wratten 8

Aero Infrared/Wratten 89B

Ektachrome Infrared/Wratten 15

Ektacolor/Wratten 2A

Plans will also be made for the application of these techniques on a practical basis to natural commercial field defoliations during the 1973 growing season.

Project Organization and Management

To be properly accomplished, resource-applications remote sensing research demands a considerable training/technique/equipment base: (1) an adequate professional education and experience background in the particular resource under study (e.g., Pathology, Forestry, Soil Science, Hydrology, Entomology, Agronomy), (2) suitable training in remote sensing applications, (3) underflight capabilities - preferably multispectral, and (4) an image analysis system which permits the highest possible level of utilization of the imagery under study. At the time of establishment of this project in the IARSL, requirements (1), (2) and (3) were (are) considered adequate to the task at hand. Item (4), however, presented a problem. Although the IARSL was fortunate to have a complete line of stereoscopic viewing equipment, light tables, projectors and a combiner for handling multispectral imagery, no density-slicing capabilities were available except on an expensive commercial contract basis at a considerable distance from St. Paul.

Permission was requested of NASA, and granted, to proceed as follows:

1. Preliminary project planning indicated a need in the way of student personnel of a half-time Research Assistant and Miscellaneous Labor amounting to a quarter-time Research Assistant (about $10,000, including University overhead charges). After deducting the

minimum essentials for field travel, field data collection, overflights, nonphotographic data analysis, and final report from the total project award, less than $1,500 was available for image preparation analysis and related travel expenses, which was totally inadequate. The project participants agreed, therefore, to absorb all student assistantship and labor costs on other projects. This was not without considerable sacrifice to these other activities, but it was felt that this remote sensing project presented an unusual opportunity to prove the Institute of Agriculture's abilities and, consequently, was given top priority.

2. The freeing of the funds which normally would have been used for personnel provided adequate funds for the purchase of an ISI VP-8 Image Analysis System. Although actual image analysis is just now getting under way, the equivalent market cost of imagery analyzed to date has already exceeded the amount which would have been available had the student assistants not been picked up financially elsewhere.

The 1972 growing season was a most difficult one from the standpoint of aerial photography. Considerable numbers of underflights, both with the IARSL multispectral camera, and with commercially contracted metric cameras, were delayed and in some cases cancelled due to persistent cloud cover. Also, a

number of "desperation" missions were flown but were aborted due to weather. On the good side, however, is the fact that all targets eventually received coverage (albeit not at the specific time originally planned) suitable for analysis and which will serve adequately as a basis for applications studies.

Publications

Douglass, R. W., M. P. Meyer and D. W. French. 1973. Remote sensing applications to forest vegetation classification and conifer vigor loss due to dwarf mistletoe. Final Report, Remote Sensing Applications in Forestry for Office of Space Sciences and Applications, NASA, by the College of Forestry, University of Minnesota. 95 pp., illus. (PUBLICATION PENDING).

Chiang, H. C., R. Latham and M. Meyer. 1973. Aerial photography, use in detecting simulated insect defoliation in corn. (PUBLICATION PENDING - Accepted for publication in the JOURNAL OF ECONOMIC ENTOMOLOGY).

Introduction

"Classification and Dynamics of Water and Wetland Resources of Minnesota."

Investigator: Dr. Dwight A. Brown, Department of Geography

Co-Investigator: Dr. Richard H. Skaggs, Department of Geography

The purpose of this investigation is to evaluate the utility of remote sensing data from both aircraft and satellite platforms for examination of wetland and surface water classification and change. The classification of resources and analysis of change is aimed at the data or information needs of several local, state, and federal agencies that manage these resources in Minnesota.

Five facets of the overall problem are currently under investigation: I. Wetland classification in the Agassiz Basin area of Minnesota, II. Rice Creek watershed management information, III. Impact of Twin Cities Metropolitan Development on Watershed Characteristics, IV. Inventory of area and dynamics of surface water resources, and V. Lake freeze-thaw and snow cover analysis. Unforseen delays in imagery and equipment aquisition have delayed the start of several areas of work until December.

The progress and involvement of various governmental agencies will be described separately for each sub-area of the investigation.

I. WETLAND CLASSIFICATION IN THE AGASSIZ BASIN AREA OF MINNESOTA

Purpose: Vast areas of Minnesota are covered by bog and wetlands. The decisions made concerning wetland use, be they drainage or preservation, ultimately will effect the total character of the environment in the North Central United States. To formulate meaningful programs and make intelligent management decisions, tools must be developed which assist the decision-maker. In this portion of the project, we are evaluating ERTS-1 imagery as a possible information source for land allocation decisions for Minnesota wetlands.

We are proceeding to test the hypothesis that ERTS-1 imagery can be used to determine general wetland catagories. It is unlikely that a general, unique answer can be provided, at least by the present project. Definitive answers may be precluded by such things as: 1) inapplicability to other portions of the state, 2) minimum detectable area, 3) the necessity for a number of seasonal aspects for positive identification of wetland types, and 4) simple lack of experience. However, we intend to outline the gross capabilities of the ERTS-1 imagery, indicate the most fruitful information processing methods, and to test our procedures on an independent data set.

Progress: We began by examining each useable ERTS-1 70mm bulk product received which covered northern Minnesota bogs. The wetland areas were then analyzed for location, size, shape and distinctness of tonal patterns. Two bogs were chosen from early

images, and each was outlined based on individual sensor bands and their composite.

We then consulted M. L. Heinselman, North Central Forest Experiment Station, who assisted us with an initial identification and provided us with his own field mapping of the area. Of the seven classes used by Heinselman, we are able to clearly identify two visually, viz., 1) Rich swamp-black spruce-feathermoss-sphagnum-leatherleaf bog forest and 2) Cedar-larch string bog and fen complex. With less reliability and using only band six, we were able to distinguish between: poor swamp forest and cedar-larch string bog and between cedar-larch string bog and rich sphagnum-black spruce-chanaedaphekalmia-leatherleaf bog forest.

In the next report period more intense identification work will be undertaken. It is extremely difficult to interpret tonal changes in the gray. Another difficulty is correlating the vegetation of one area with the vegetation of another with only gray as a guide when the same tone of gray can represent such a wide variety of colors in each color band or in the band combinations. We shall examine color compositing and intensity level slicing as means of eliminating these difficulties.

II. RICE CREEK WATERSHED DISTRICT MANAGEMENT

Purpose: The State of Minnesota has statutory provisions for establishing Watershed Districts which are local governmental units charged with maintaining water quantity and quality and with developing flood protection measures. A primary obstacle facing both existing and recently established watershed districts is the great difficulty and expense in acquiring reliable and current data. It is tedious and costly to carry out extensive field study operations as a means of data collection. A portion of this project is dedicated to developing a means of acquiring from ERTS-1 imagery data for watershed management. If it is possible to draw upon ERTS-1 data for watershed management, information could be distributed to the districts within Minnesota.

The initial step in attempting to apply the ERTS-1 images as a data bank for watershed management is to acquire experience in interpreting the ERTS-1 data for the explicit data types desired by watershed managers. A highly detailed analysis of one sub-watershed is being compiled to act as an example of the kind of data and degree of accuracy that is needed from the ERTS-1 imagery.

Using high altitude photography, topographic maps, storm sewer maps and field observation highly detailed maps can be developed as ground truth. Since watershed managers require rather precise data on small areas it is unlikely that direct visual interpretation of ERTS-1 images will be fruitful, although we shall try. Rather, we are counting on electronic processing of the separate spectral bands and their combinations to provide

surrogate indicators. If surrogates are found, a portion of our goal will be completed, but more work must be completed before one can directly move on to interpret information for other watershed districts. Care must be taken that a-priori knowledge does not add detail that cannot be expected elsewhere.

A second step then must be to test the interpretation in another portion of the watershed which will be analyzed by means of the ERTS-1 imagery and compared to data provided by the watershed managers. Thus the abilities and limitations can be assessed.

Progress: Thus far we are still working to complete the initial aim, the construction of an accurate sub-watershed map to use in conjunction with the ERTS-1 data. In cooperation with the new Rice Creek Watershed and their consulting engineers, Hickok and Associates, we are developing the detailed data for the Pike Lake sub-watershed. At the request of the watershed managers, the project is developing maps that pertain to current methods of watershed management so that the data collected can be put to immediate use.

In compliance with a request from Hickok and Associates an accurate watershed of Pike Lake has been developed from high altitude IR aerial photographs used in stero pairs, storm sewer maps, topographic maps, and limited field observation. With the outline in hand, calculations and mapping is progressing.

The initial land use map requested is nearly complete, and it includes classifications requested by the engineers as being helpful in their work, viz.,

I Residential -- Four units + per acre
1/2 - units per acre
less than 1/2 per acre

II Industrial -- Downtown
Old Suburban
New Suburban

III Commercial -- Downtown
Old Suburban
New Suburban

IV Open Space

V Lakes and Streams

Although not chosen by us, we feel it is important to offer the map for use by those currently involved in watershed management.

A second analysis that will be developed is a vegetation map that can be used to detect high water marks as indicated by vegetation change. These data are to be placed in immediate use for flood plain management with the watershed district.

It should be emphasized that all of our planned current work is that prescribed by those already working in watershed management so that any data derived from high altitude aerial photography and ERTS-1 imagery will be put to use immediately by watershed management work.

III. IMPACT OF THE TWIN CITIES METROPOLITAN DEVELOPMENT ON WATERSHED CHARACTERISTICS

Purpose: The purpose of this research is to gain an overview of the gross changes in surface cover that effect runoff and infiltration in the seven county metropolitan area. The basic data resources being utilized are the Original Vegetation Map of Minnesota by Marschner, 1:120,000 color infrared photography, flown 6 June 1972 by NASA, MSC, and October 6, 1972 ERTS-1 color composite image of the metropolitan area at a 1:250,000 scale obtained from the EROS Data Center.

This effort is being undertaken with the expressed interest of the Water Resources Group of the Metropolitan Council Staff. They have agreed to offer evaluation and guidance as to how remote sensing data can best support their data needs. Wherever possible their suggestions will be incorporated in the final analysis so that both the end product and the technology will be of maximum possible benefit in their work.

Progress: The Marschner original vegetation map of 1930 exists only in two hand-colored copies held by the North Central Forest Experiment Station. These manuscript maps were loaned for the purpose of making color 35mm photographic slides. The conversion of the mapped information from slides to a 1:250,000 base map of the seven county metropolitan area should be completed by January 12th. A data grid for interpretations of the high altitude aerial photography has been completed and preliminary interpretation will begin January 15, 1973. The ERTS 1:250,000 color image was received January 10, 1973 and data extraction will begin shortly after January 15,1973.

IV. INVENTORY OF AREA AND DYNAMICS OF SURFACE WATER RESOURCES

Purpose: This work involves developing a procedure for a rapid inventory of surface water resources. Sample areas will be set up for developing and testing water area measurement procedures from ERTS-1 imagery.

The potential for a surface water inventory is of interest to the Minnesota Department of Natural Resources. Seasonal fluctuations as well as longer term fluctuations are also important in managing land use and development near these water areas, particularly since the passage of the Lake Shore Zoning Act, which requires this type of data for proper enforcement.

Progress: Several lake basins have been selected for monitoring change. These have been mapped for several different periods from the 1930's to the present using existing aerial photography. Further progress in this part of the project must now await delivery of electronic scanning equipment that is scheduled for delivery in the week of January 15, 1973.

V. LAKE FREEZE UP AND THAW AND SNOW COVER ANALYSIS

Purpose: This phase of the project is directed toward evaluating the contribution of repeated ERTS coverage of Minnesota Watersheds to understanding the response of surface water to the moisture and thermal energy regime. The information derived may allow the evaluation of the location of snow moisture content measuring sites for different purposes and an evaluation of the role of land use on rates of snow melt.

Progress: Because of the seasonal nature of this project, work is not scheduled to begin until late winter. Considerable imagery has been arriving that will be useful if we can follow sufficient sample areas through the thaw period.

Introduction

"Studies of Lake Superior Bay."

Investigator: Dr. Michael Sydor, Department of Physics,
University of Minnesota, Duluth

One part of our program concerns environmental studies of the St. Louis River bays and the adjacent Lake Superior waters. Our allotted NASA funds are spent mostly on employment of one graduate physics student who will use the project for his dissertation. Our other help is funded from other sources. One undergraduate student is employed under cooperative arrangement with the City of Cloquet. One biology undergraduate was donated to the project in cooperation with Dr. Odlaug, and his project concerning his studies of environmental impact due to Harbor Dredging (under contract to U.S. Army Corps of Engineers). In addition, one chemistry student will join the program under supervision of Dr. Caple of the Chemistry Department.

PROJECT OBJECTIVES: 1. The City of Cloquet has problems with water quality at their Lake Superior intake.

The causes of their problems are:

a. Turbidity caused by bottom currents produced by water pileup at western end of Lake Superior due to winds.

b. Water discoloration and odor during the months of ice cover on Lake Superior.

The first cause is largely due to natural lake activity, which could have been foretold, particularly if aerial data on Lake Superior during prolonged N.E. winds was available (ground data was not available simply because it is too hazardous to collect it at such times). We believe that the problem is further aggravated by the fact that harbor dredgings were dumped in the lake by the U.S. Army Corps of Engineers. This could be easily verified when the aerial data becomes available since the outline of dumping area is known.

The effluents from the Nemadji River present a problem during the severe runoff time, but this problem is of secondary importance.

During the summer when the wind activity is low, the water quality at the Cloquet intake is good. This is largely because the prevailing currents sweep out the polluted waters flowing from St. Louis River into the lake. These purging currents disappear or become negligible in the winter during the time of ice cover on the lake. Then the stagnant, polluted water accumu-

lates near the intake. The odor may be due to lack of oxidation and the accumulation of hydrogen sulfide. The chemistry student will be used in investigating the water odor problem. Weekly measurements are being made on the water quality at the intake and the lake entries, to correlate the effects of effluents on the water quality at the intake. We have support of the chief engineer for Cloquet City, Mr. B. Boyer, on this program.

Currently the City has approved construction of a filtration plant at Cloquet. It is our belief, and Mr. Boyer's, that such expenditure would be costly and short-sighted. For one, it is pointless to pump dirty water past present and potential water users, such as the City of Superior.

It would be much more reasonable to build a filtration plant near the intake. Furthermore, the intake may be relocated to a better area. The aerial data from ERTS for August 12 confirms this. However, to evaluate the possibility of this very economically tempting proposition, more extensive aerial data taken at proper times is essential to establish the extent and pattern of turbid water caused by bottom activity and effluents from the Superior Entry. Similarly aerial data on ice cover and water quality at various points on the lake. ERTS-1 data will help, but it is not sufficient for short-range use because it is taken on too infrequent basis. This is the reason why we requested manned aircraft support.

The U.S. Army Corps of Engineers is testing an experimental bubbler system in the Superior bay. They are working on the

extension of shipping season in the bay throughout the year. The development of winter shipping would have serious repercussion on the water quality and the environment of the bay and the adjacent Lake Superior waters. This matter was already discussed in our request for manned aircraft support.

We are working in close cooperation on this problem with the local office of the U.S. Army Corps of Engineers (Mr. Clarence Wang, the local chief administrator). We have also discussed these problems with Mr. A. Blomquist of the Biocentric Incorporated. His company is under contract to the Corps of Engineers. Mr. Blomquist is interested in having our cooperation on aconsulting basis. I have taken the liberty to offer him all the information that I have available, at cost of publication expenses only. Since we are a government institution, I felt that that was the correct attitude to take, subject to the consent of the principal investigator, Laurence Cahill.

PROJECT OBJECTIVES: 2. The investigation of water transport in the extreme western arm of Lake Superior will resume in the spring.

This activity is related to the above problem, but concerns really a separate project. In this program we are concerned primarily with measurements of water currents at all depths in the extreme western end of Lake Superior, and the measurements of turbidity caused by sedimentary plumes and bottom activity associated with the thermocline fluctuations. The latter is correlated with remote sensing data for the western end of the lake, which is relatively shallow and is subject to turbidity caused by the water currents above thermocline.

The results of last summer's investigation indicate a current reversal below the thermocline depths. This result is important in dispelling the erroneous notion that the dumping of the taconite tailings near Silver Bay would automatically affect the water quality at the Duluth water intake if the tailings transport was really as extensive as some people claim. The Duluth intake is often below the thermocline and does not lie in direct current path from Silver Bay. Studies of the Knife River plume reveal that the leading edge of the plume is thin, showing that very fine silt is confined to surface waters. It also shows a relative lack of mixing of warmer effluents with the lake waters, giving support to the belief that very fine taconite tailings often remain suspended in the surface waters, giving rise to the observed green which comes about from scattering of light by the suspended particles.

Currently we are pressed for help. I could use another graduate student on the project. Right now we do not have adequate help for collecting the data in the field. (I go out with the students myself, as a crew of at least two persons is necessary for safety reasons. However, their time is limited due to course work.) Furthermore, we need to make extensive preparation for the summer. In the way of equipment I could use two items:

a. A truck for transportation. (We now use our own cars.) We could get one surplus for $120 and a total expense for insurance, maintenance and the truck of $500.

b. Snow conditions and the fact that no road is available along the Minnesota Point would make a snowmobile more than pay for itself, so far as time taken to get to sampling station is concerned. I have established very good ties with the U.S. Army Corps of Engineers at Duluth. They have a snowmobile that they use for their experimental bubbler. I will ask them to let me have it after the operation of the bubbler ceases in February.

I am counting on using D. Brown's reducing equipment for the aerial data.

I would also ask you to request for me the computer programs necessary to extract data from computer compatible tapes. In the long run, this may be my alternative to purchasing of optical and electronic photograph reducing equipment. We have the machine time and expert computer help necessary.

Introduction

"Feasibility of Detecting Major Air Pollutants by Earth-Oriented Satellite-Borne Sensors."

Investigator: Dr. Harold J. Paulus, Department of Environmental Health

A thorough search of the literature conducted to determine the present state of the art of air pollutant determinations by remote sensors is nearing completion. Publications such as: "Peaceful Uses of Earth-Observation Spacecraft", "Study of Air Pollutant Detection by Remote Sensors", "Remote Measurement of Pollution", and other NASA contracted studies were helpful in explaining previous work completed in the area of air pollution detection. Communications with other groups on the ERTS project included a session with Dr. Dwight Brown from the Department of Geology and Geography. Imagery of the Minneapolis metropolitan area from the ERTS satellite were viewed at that time. The films were of considerable interest and showed much promise for atmospheric studies.

Informal discussions were held with Mr. Edward Wilk, Chief of Air Quality Section, and Dr. John Olin in charge of monitering and data reduction for the Minnesota Pollution Control Agency. Mr. Wilk and Dr. Olin expressed interest in the ERTS project and indicated a desire to be informed of its progress.

More recently, a seminar was presented before the entire Environmental Health Department of the School of Public Health. Methods of remote sensing were discussed and visual aids were employed to illustrate some of the many areas of study to which ERTS may be applied. The seminar was well received by both staff and students.

Future plans for this year include a visit to the EROS Data Center in Sioux Falls for additional aid in data interpretation procedures. Further discussion on the rise of ERTS data and results will be held with the Minnesota Pollution Control Agency personnel.